

## American College of Radiology ACR Appropriateness Criteria®

**Clinical Condition:** Acute Trauma to the Knee

**Variant 1:** Patient any age (excluding infants)–fall or twisted injury, no focal tenderness, no effusion; able to walk.

Radiologic Procedure	Rating	Comments	<a href="#">RRL*</a>
CT knee	2		Min
US knee	2		None
NUC bone scan (SPECT/TPBI)	2		Med
X-ray knee	2		Min
X-ray arthrography knee	2		Min
MRI knee	2		None
MRA lower extremity	2		None
<b><u>Rating Scale:</u></b> 1=Least appropriate, 9=Most appropriate			<b>*Relative Radiation Level</b>

**Variant 2:** Patient, any age (excluding infants)–fall or twisting injury, with one or more of following: focal tenderness, effusion, inability to bear weight. First study.

Radiologic Procedure	Rating	Comments	<a href="#">RRL*</a>
X-ray knee	9		Min
MRI knee	5		None
US knee	2		None
CT knee	2		Min
NUC bone scan (SPECT/TPBI)	2		Med
X-ray arthrography knee	2		Min
MRA lower extremity	2		None
<b><u>Rating Scale:</u></b> 1=Least appropriate, 9=Most appropriate			<b>*Relative Radiation Level</b>

An ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists, and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those exams generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

**Clinical Condition:****Acute Trauma to the Knee****Variant 3:****Injury to knee 2 days ago, mechanism unknown. Focal patellar tenderness, effusion, able to walk.**

Radiologic Procedure	Rating	Comments	<a href="#">RRL*</a>
X-ray knee	9		Min
MRI knee	5		None
X-ray arthrography knee	2		Min
CT knee	2		Min
MRA lower extremity	2		None
NUC bone scan (SPECT/TPBI)	2		Med
US knee	2		None
<b>Rating Scale:</b> 1=Least appropriate, 9=Most appropriate			<b>*Relative Radiation Level</b>

**Variant 4:****Significant trauma to knee from motor vehicle accident, suspect posterior knee dislocation.**

Radiologic Procedure	Rating	Comments	<a href="#">RRL*</a>
MRI knee	9		None
X-ray knee	9		Min
MRA lower extremity	7	If MRA chosen, MRI will be done at same time.	None
US knee	2		None
CT knee	2		Min
NUC bone scan (SPECT/TPBI)	2		Med
X-ray arthrography knee	2		Min
<b>Rating Scale:</b> 1=Least appropriate, 9=Most appropriate			<b>*Relative Radiation Level</b>

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## ACUTE TRAUMA TO THE KNEE

Expert Panel on Musculoskeletal Imaging: Helene Pavlov, MD<sup>1</sup>; Gregory R. Saboeiro, MD<sup>2</sup>; Scot E. Campbell, MD<sup>3</sup>; Murray K. Dalinka, MD<sup>4</sup>; Richard H. Daffner, MD<sup>5</sup>; Arthur A. De Smet, MD<sup>6</sup>; George Y. El-Khoury, MD<sup>7</sup>; John B. Kneeland, MD<sup>8</sup>; B.J. Manaster, MD, PhD<sup>9</sup>; William B. Morrison, MD<sup>10</sup>; David A. Rubin, MD<sup>11</sup>; Robert Schneider, MD<sup>12</sup>; Lynne S. Steinbach, MD<sup>13</sup>; Barbara N. Weissman, MD<sup>14</sup>; Robert H. Haralson III, MD.<sup>15</sup>

### Summary of Literature Review

There are 1.3 million annual visits to United States emergency departments because of acute knee trauma [1]. It is estimated that in the United States, more than one million knee radiographs are performed annually for patients with acute knee pain [2-5]. According to Verma et al [1], over \$1 billion are spent on radiographs of the knee. The knee radiograph is the most common radiograph performed for trauma in the emergency room and has the lowest yield for diagnosing clinically significant fractures [5,6-12]. Of 1,296 patients with knee injuries, 68.6% had radiographs, of which 93.4% were negative for fracture [12]. Retrospective review of 1,967 patients with acute knee injuries revealed that 74.1% of patients had radiographs and only 5.2% had fractures [12]. In a study of 1,727 patients, 92.4% radiographs were negative for fracture [9,12], an even lower rate for positive radiographs than that reported for the ankle [13-15]. Fishwick et al [16] concluded that radiographs obtained for acute trauma do not reliably depict all important injuries and that 25% of knee radiographs obtained for acute trauma do not correlate with the clinical findings. Weber et al [11] reported that the patella was the most common bony fracture after acute knee injury. Fractures missed on clinical examination included fractures of the patella, tibial spine, and fibular head [11].

A prospective survey of the judgment and attitudes of experienced clinicians in the use of knee radiography in 1,040 patients with acute knee injuries showed that despite having the ability to accurately predict the probability of fracture and to discriminate between fracture and nonfracture cases, radiographs were usually ordered. The proportion of patients referred for knee

radiographs varied from 65.9%-84.6% [12]. According to the physicians, radiographs were ordered for the following reasons: 1) patients expected it and would otherwise be dissatisfied; 2) the physician lacked confidence in the clinical examination, or the orthopedic surgeon considered the radiograph routine; and 3) possible medicolegal repercussions [12,15,17,18]. These reasons and the insistence of patients for imaging were recognized recently as the reasons implementation of the guidelines was not overwhelming [1].

Stiell et al [19], Seaberg and Jackson [2], Bauer et al [20], and Saxena et al [21] proposed clinical decision rules for the acutely injured knee. Data from multiple studies suggests that the radiographic examination of the knee following acute injury can be eliminated in most instances with the application of specific clinical guidelines. A prospective and retrospective study of 334 patients reported that for patients between 12 and 50 years of age suffering a fall or blunt trauma and unable to ambulate or had multiple trauma should be radiographed [2]. They reported 92% sensitivity and 79% specificity for identifying clinically significant fractures. Their study also reported that applying the clinical decision rules could reduce the number of radiographs taken in the emergency room by 78% [2].

Stiell et al [8] applied a clinical decision rule using parameters based on age, palpable tenderness, and function. Patients with acute knee pain and one or more of the following parameters should have a radiographic examination if they:

- Are 55 years of age or older;
- Have palpable tenderness over the head of the fibula;
- Have isolated patellar tenderness;
- Cannot flex the knee to 90°;
- Cannot bear weight immediately following the injury; or
- Cannot walk in the emergency room (after taking four steps).

These rules were applied prospectively in 1,047 adults with acute knee injuries and it was determined that application of the rule would result in a 28% relative reduction in the number of radiographs ordered, a decrease from 68.6%-49.4% [8].

Weber et al [11] concluded that a clinically significant fracture can be excluded in patients older than 18 years who can walk without limping or if there was a twisting injury to the knee and no joint effusion. If an effusion was present on physical examination, the odds of a fracture were 7.5 times greater [11]. Using these clinical decision rules, the sensitivity for detecting a knee fracture was

<sup>1</sup>Principal Author, Hospital for Special Surgery, New York, NY; <sup>2</sup>Research Author, Hospital for Special Surgery, New York, NY; <sup>3</sup>Research Author, Hospital for Special Surgery, New York, NY; <sup>4</sup>Panel Chair, University of Pennsylvania Hospital, Philadelphia, Pa; <sup>5</sup>Allegheny General Hospital, Pittsburgh, Pa; <sup>6</sup>University of Wisconsin, Madison, Wis; <sup>7</sup>University of Iowa Hospitals and Clinics, Iowa City, Iowa; <sup>8</sup>University of Pennsylvania Hospital, Philadelphia, Pa; <sup>9</sup>University of Colorado Health Science Center, Denver, Colo; <sup>10</sup>Thomas Jefferson University Hospital, Philadelphia, Pa; <sup>11</sup>Washington University of St. Louis, St. Louis, Mo; <sup>12</sup>Hospital for Special Surgery, New York, NY; <sup>13</sup>University of California, San Francisco, Calif; <sup>14</sup>Brigham & Women's Hospital, Boston, Mass; <sup>15</sup>American Academy of Orthopaedic Surgeons, Chicago, Ill.

Reprint requests to: Department of Quality & Safety, American College of Radiology, 1891 Preston White Drive, Reston, VA 20191-4397.

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100%, and specificity was sufficient to eliminate the need for 29% of knee radiographs ordered in the emergency room [11].

A later study [22] was performed to validate the previous decision rule [8] and prospective validation, analyzing 1096 patients, found the decision rule to be 100% sensitive for identifying knee fractures. The decision rule was interpreted correctly 96% of the time, and when applied, the probability of missing a fracture was 0% [22]. The decision rule was 100% sensitive for identifying a fracture in patients older than 18 years who were not referred from another hospital, returned for reassessment, had a knee injury for 7 days, or had isolated skin lesions. The potential relative reduction in use of radiography was estimated to be 28%, (from 74%-53%) [12,22].

In a pooled analysis of data from six studies, Bachmann et al [23] concluded that a negative result on the previous decision rule [8] accurately excluded knee fracture after acute knee injury [23].

A recent study [24] compared the implementation of the previous decision rule [8] by triage nurses and emergency medicine physicians. No fracture was missed by either group, but triage nurses were found to order 3.6 times more radiographs than emergency physicians, maintaining sensitivity at the expense of specificity and cost savings [24]. Ketelslegers et al [25] evaluated the use of the previous decision rule [8] when applied by users with different levels of clinical training, including medical students and surgical residents, and found sensitivity and negative predictive value of 1.0 for both groups, and reduced radiography rate of 25% with application of the decision rule [25].

Verma et al [1], in a study of 214 patients, determined that the use of radiographs in the setting of acute trauma could be further reduced by obtaining a single lateral view. It was reported that the probability of not having a fracture if the lateral view was normal was 100%, thus reducing the need for additional radiographs by 67% [1].

With regard to mechanism of injury, history and the physical examination are key elements to determining the indication for radiographs and the application of the decision rules. The most common mechanisms for knee injury are a direct blow, a fall, or a twisting injury [11,12]. Twisting injuries are responsible for three-fourths of all knee injuries; however, 86% of all knee fractures result from blunt trauma [11,12]. Odds for a fracture are 3.6 times greater with blunt trauma than with a twisting injury [7]. The risk of fracture also increases with age; fracture is four times greater in patients older than 50 years, presumably secondary to osteoporosis, increased frequency of blunt injury, and inability to protect the knee during a fall [11].

Absence of immediate swelling, ecchymosis, effusion, deformity, increased warmth, and abrasion/laceration are significant predictors of a normal radiograph [21]. It was generally agreed that radiographs should be obtained and that the clinical decision rule should not be applied for patients with gross deformity [11], a palpable mass [21,22], a penetrating injury, prosthetic hardware, unreliable clinical history or physical exam secondary to multiple injuries [11,22], altered mental status (eg, dementia, head injury, drug or alcohol use) [11,22], neuropathy (eg, paraplegia, diabetes) [11,21,22], or history suggesting increased risk of fracture [21]. The physician's judgment and common sense, however, should supersede clinical guidelines [11].

In addition to clinically significant fractures, other injuries must be considered. Most patients (93.5%) who present with acute knee injuries in the emergency room have soft-tissue rather than osseous injuries [8]. Even in patients with fractures, concomitant soft tissue injuries frequently are present [26]. Shepherd et al [26] found that in 90% of patients with otherwise nonoperative tibial plateau fractures there were significant soft tissue injuries diagnosed by MRI, including ligament and meniscal tears [26]. Radiographs usually do not help to identify meniscal or ligamentous injuries, and initial diagnosis usually depends on the clinical examination [27]. A joint effusion on the radiograph may help indicate bone or soft-tissue injury, but this is usually clinically evident [7,28,29]. Occasionally, a radiograph of a specific fracture may identify a ligamentous disruption [30-35]; however, other imaging modalities, particularly MRI, are often needed for diagnostic confirmation. An accurate clinical exam is essential to identify patients at high risk for delayed function recovery due to major soft-tissue injuries. Decision rules for soft-tissue knee injuries are currently being developed [22]; however, it is recognized that MRI is the optimal imaging modality for identifying soft-tissue, cartilaginous surface, and bone injuries around the knee compared to radiograph.

To image internal knee derangement, MRI is the technique of choice [36,37]. Accuracy and reliability of MRI depend on experience and training [38]. Magnetic resonance has been shown to demonstrate minor meniscocapsular tears when performed with understanding of anatomy [39]. Multiple authors and studies have validated that unnecessary diagnostic arthroscopy can be avoided given the high predictive values of a negative MRI [40-42]. One study found MRI accurate with a positive predictive value twice that for meniscal tears compared to the clinical examination. It also found MRI would reduce a resultant negative diagnostic arthroscopy to 5% and would be further helpful in reducing the need for a second therapeutic arthroscopic procedure [43]. Previous reports identified MRI accuracy as approximately 94% and showed that it can effectively

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replace diagnostic arthroscopy for evaluation for meniscal and ligamentous tears [36]. Another more recent study reported that when the clinical exam is equivocal within 6 weeks of sudden trauma and a hemarthrosis, MRI could have prevented diagnostic arthroscopy in 22% of patients [44]. The quadriceps and patellar tendons can also be assessed accurately by MRI.

MRI has had an impact on treatment and with pathogenic mechanism of disease [38]. One study concluded that horizontal degenerative tears in patients older than 50 years are best left alone and may be asymptomatic, while acute tears are best treated with immediate repair [45-47]. MRI is a valuable tool in the decision-making process, altering the treatment plan in 18% of patients with meniscal or chondral surface injuries, and allowing earlier surgical intervention given the more accurate diagnosis obtained [43,48-50]. A recent study found accuracies of 95% and 99% for ACL and PCL tears, respectively, 85% and 91% for medial and lateral meniscal tears, respectively, and 91% for articular cartilage injury [51].

An acute ACL rupture is responsible for more than 70% of all acute hemarthrosis in young athletes [54] and 17% in a mixed sedentary and athletic population [53]. Locking and loose body on radiograph and hemarthrosis within 12 hours of injury have previously been reported as indications for arthroscopy instead of MRI [34,37,54]. However, a recent study found that in 48% of patients presenting with an acutely locked knee, management was changed from surgical to conservative based on MRI findings [55].

In addition to MRI, single photon emission computed tomography (SPECT) has been proposed for diagnosing meniscus injuries [56,57]. A specific crescentic pattern of uptake on the transaxial view has been described as having a sensitivity of 77% and specificity of 74%, and with the additional criterion of increased equilibrium activity in the adjacent femoral condyles, a sensitivity of 90%, and an 84% accuracy to identify a meniscal tear [58]. Similarly, sonography has been reported to be 91% sensitive and 100% specific for diagnosing an acute ACL tear in a patient within 10 weeks of an acute hemarthrosis, and who has no prior trauma and no bone abnormalities [57]. Ultrasound was shown to be as reproducible and reliable as the KT-1000 device (89 and 133 Newton and manual maximum force) and can be used both for initial detection or confirmation of the injury and for follow-up [59]. In addition, spiral CT with 3D reconstruction has been shown to more accurately reflect the severity of tibial plateau fractures than radiography in 43% of cases, and to modify the surgical plan in 59% of operative cases [60].

In patients 16 to 35 years of age, with normal radiographs, an occult impaction or stress fracture may clinically simulate a soft-tissue injury (including meniscus or

capsuloligamentous disruptions) and may present with acute pain and functional limitations [61-66]. The prevalence of occult posttraumatic injuries has been shown to approximate 72% [63]. If there is no cortical involvement, radiographs will usually be normal. Both triple-phase bone scan (TPBS) and MRI are highly sensitive for detecting bony healing (microvasculature disruption, hyperemic blood flow, and osteometabolic hyperactivity) [60]; fast spin echo MRI sequences with fat saturation (FSE-FS) are especially sensitive for identifying bone trauma [67-69]. TPBS however, is insensitive for detecting of microfracture or anatomic extent of injury. These bone lesions have been shown to respond to aggressive nonweight bearing to prevent further injury to bone and to preserve the subchondral bone from collapse and the joint from secondary osteoarthritis [46,65,70].

A lateral patellar dislocation can also simulate a medial ligamentous injury [71,72]. This injury usually results from a twisting injury in which the femur is internally rotated on a fixed foot and tibia, and in which there is additional contraction of the quadriceps muscle or blow to the outside of the knee. Patients typically present with a tense, swollen knee and a positive apprehension test [73-75]. Fractures may be seen on radiograph, and osteochondral changes and medial retinaculum injuries may be evident on MRI. Surgery is usually not indicated [71]. A complete dislocation of the knee results from a fall from height, motor vehicle accident, vehicle striking a pedestrian, or contact sports [76-79]. This injury usually reduces spontaneously, and the extent of dislocation may be underestimated. Extensive ligamentous disruption, instability, and palpable hematoma are frequent [80-82]. This injury constitutes a true orthopedic emergency because of possible nerve or arterial damage [74,81-84]; vascular injury is a finding in one-third of patients following posterior knee dislocation [85]. Physical signs of clinically significant vascular injury are the absence of pulses, ischemia, active bleeding, and bruit/thrill; these injuries have 100% accuracy for determining the need for a surgical explanation [85]. Routine use of arteriography is not warranted in treatment of these patients, and Yu et al [79] endorse MRI only when evidence of an acute popliteal artery injury is absent. In the presence of ischemia or lack of pulses to the lower extremity, surgical exploration is suggested [79] following magnetic resonance angiography (MRA) or Doppler. An MRI should also be performed to identify ligamentous injuries and associated pathology [86-88]. Additionally, it has been reported that bicruciate ligament injuries equate to a knee dislocation in terms of severity of ligamentous injury and frequency of major arterial injuries [89]. Potter et al [90] found excellent correlation between MRI findings and surgical findings ( $\kappa > 0.8$ ), and 100% correlation between MRA findings and conventional angiography

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findings in multiple-ligament injured knees, including knee dislocations [90].

### Summary

Clinical decision rules for evaluating the acutely injured knee have been studied by various investigators, who determined that their application can considerably reduce the number of radiographs ordered without missing a clinically significant fracture. Although different parameters and definitions were used for the various decision rules, there were sufficient similarities between the investigations to allow usable conclusions to be drawn.

In patients of any age except for infants, the clinical parameters used for not requiring a radiograph following knee trauma are as follows:

- Patient is able to walk without a limp [11];
- Patient had a twisting injury and there is no effusion [11].

The clinical parameters for *ordering* knee radiographs in this population following trauma are as follows:

- Joint effusion within 24 hours of direct blow or fall [11];
- Palpable tenderness over fibular head or patella [8];
- Inability to walk (four steps) or bear weight immediately or in the emergency room [8] or within a week of the trauma [1];
- Inability to flex knee to 90° [8].

It was determined that normal radiographs could be expected in the *absence* of immediate swelling, ecchymosis, deformity, increased warmth, or abrasion/laceration [21]. It was further stated that a fracture could be excluded if the single lateral view of the knee was normal, eliminating the need for additional radiographic views [1]. In general, these studies excluded patients with superficial skin injuries, gross deformity, a palpable mass, a penetrating injury, prosthetic hardware, altered consciousness (from alcohol and drug use), multiple injuries, decreased limp sensation, or a history indicating an elevated risk of fracture. They also excluded pregnant patients, and those who were returning for reassessment and patient with injury for more than seven days [2,11,21,22].

In addition to the clinically significant fractures, occult bony injuries may occur that are not evident on radiograph and are best diagnosed on MRI or TPBS. Newer MRI techniques are very sensitive and specific to these lesions [64,67-69]. The TPBS is sensitive but cannot determine the exact anatomical injury [64].

Although lateral patellar dislocation may be reduced at the time of presentation in the emergency room, there is

usually focal patellar tenderness on clinical exam. The injury is associated with a definite pattern of bony injuries on radiographs and on the MRI examination; a medial reticulum injury may also be evident. These patients typically do not require surgery. A complete knee dislocation, even if spontaneously reduced, constitutes a potential threat to the popliteal nerve or artery. Magnetic resonance angiography or Doppler should be performed to evaluate the artery. If MRA is performed, an MRI should also be performed to identify ligamentous injuries and associated pathology [86-88]. Additionally, it has been reported that a bifurcate ligament injury equates to a knee dislocation in terms of severity of ligamentous injury and frequency of major arterial injuries [89].

Decision rules for the evaluation of soft-tissue injuries are being investigated and have not yet been published [22]. Soft-tissue injuries (meniscal injuries, chondral surface injuries, and ligamentous disruption) are best evaluated by MRI [36,37,40-43,48-50,91,92]. In addition to MRI, SPECT has also been reported to be accurate for diagnosing meniscal injuries [56,58], while sonography has been shown to be diagnostic for acute ACL injuries in the presence of a hemarthrosis or for follow-up of ACL injuries [57,59].

As with ankle injuries [89,93-95], decision rules are applicable to patients with an acutely injured knee and can significantly decrease the use of radiographs without the likelihood of missing a clinically important fracture. More than 92% of radiographs for acute knee pain in the emergency rooms across the United States are negative for fractures [1,16,22]. The knee exam in the emergency room exemplifies how many low-cost but high-volume tests contribute as much to the escalating health care costs as high-cost but low-volume procedures [1,16,22,96,97]. A decrease in the inappropriate usage of radiographs could in theory result in a shorter waiting time in emergency rooms and radiograph departments, and also decrease costs for the health care system without loss of quality [1,16].

### Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® [Radiation Dose Assessment Introduction](#) document.

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Relative Radiation Level Designations	
Relative Radiation Level	Effective Dose Estimate Range
None	0
Minimal	< 0.1 mSv
Low	0.1-1 mSv
Medium	1-10 mSv
High	10-100 mSv

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